PB87-152641

Sampling Considerations for Particles and Semivolatile Organic Compounds in Indoor Environments

(U.S.) Environmental Monitoring Systems Lab.
Research Triangle Park, NC

Jan 87

U.S. Department of Commerce
National Technical Information Service
NTIS

PB87-152641

EPA/600/D-87/053
January 1987

SAMPLING CONSIDERATIONS FOR PARTICLES AND SEMIVOLATILE ORGANIC COMPOUNDS IN INDOOR ENVIRONMENTS

by

Charles E. Rodes
Environmental Monitoring Systems Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/D-87/053	2.
3. RECIPIENT'S ACCESSION NO. PB87 152641/AS	
4. TITLE AND SUBTITLE Sampling Considerations for Particles and Semivolatile Organic Compounds in Indoor Environments	5. REPORT DATE January 1987
	6. PERFORMING ORGANIZATION CODE MAD
7. AUTHOR(S) Charles E. Rodes	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Same as Item (12) below	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE EPA/600/08

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Potential problem areas that can be encountered when sampling particles or SVOC's indoors are discussed. Emphasis is placed on careful definition of study objectives and defining the needed data quality. Specific areas covered are precision, accuracy, obtrusiveness, utility outdoors, particle size distribution and filter substrates. Tables are provided on the amount of particles and selected semivolatiles that must be collected for subsequent analyses.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS (This Report) UNCLASSIFIED	21. NO. OF PAGES 17
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

SAMPLING CONSIDERATIONS FOR PARTICLES AND SEMIVOLATILE ORGANIC COMPOUNDS IN INDOOR ENVIRONMENTS

by

Charles E. Rodes
Environmental Monitoring Systems Laboratory
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

The sampling considerations for pollutants found indoors can be substantially different from those for pollutants found outdoors. This is especially true for both particles and semivolatile organic compounds (SVOC's) because they are not uniformly distributed in the air. Suspended particles indoors or outdoors exist as a distribution of particle sizes which changes with convective motion as the larger particles settle or are lost on surfaces. The low vapor pressure organics described as SVOC's are distributed between the vapor phase and the particulate phase, primarily as functions of the ambient temperature and compound vapor pressures. The SVOC's are loosely defined as those having saturation vapor pressures between 10^{-6} and 10^{-1} Pa at 25°C.

A measurement at a given point in time may be extremely accurate, but not representative of the exposure that is occurring in the indoor microenvironment. Exposure measurement is a key component of survey methodology to produce accurate risk assessments. As with other types of measurements, compromises are made in indoor sampling to expedite the process or reduce the obtrusiveness to residents, often leading to collection of a sample with inadequate mass for satisfactory precision or subsequent speciation. Particulate monitors which use built-in detectors, such as those based on optical or piezoelectric principles, are not considered here because their comparative precisions and accuracies are not well known. The present focus is on techniques which draw a sample through a filter substrate.

SAMPLING OBJECTIVES

Many potential sampling problems can be resolved, or at least defined clearly as limitations, simply by carefully defining the sampling and quality assurance objectives. The ultimate user of the collected information and the needed data quality parameters should be described at the outset as the bases for all subsequent sampling decisions. The sampling objectives are then defined by the way the data will be analyzed and interpreted by the ultimate user. Most indoor sampling studies are either research efforts to characterize various aspects of the indoor microenvironment or attempts to define the magnitude of a specific problem or complaint in a reasonably short time. Less typically some studies have addressed building long-term data bases from which to make decisions on either source control techniques or possible regulatory actions. If the objective is problem definition, such as an occupant complaint, the sampling period is necessarily short. A minimum acceptable data quality requires that if the sampling time is shortened, steps should be taken to improve the precision and accuracy with higher sampling flowrates and at least some attempt to address representativeness.

Characterization studies of the indoor microenvironment have often defined the spatial and temporal gradients to better determine how single measurements represent the indoor exposure. In order to add the element of measured exposure assessment to the indoor sampling objective, the samplers must be small enough to be carried with or worn by the occupant. Currently available particulate exposure monitors (PEM's) have proven to be less than satisfactory because of either their low sampling rates (1-2 ℓ/min or less) resulting in minimal collection on the substrate(s), or their obtrusiveness. This forces either a modification to the objectives or an alternative approach to exposure assessment based on one or more fixed location measurements selected to approximate the true microenvironmental exposure.

Invariably the cost of collecting and analyzing particle and SVOC samples also enters into the definition of objectives as does the number of samplers available. These very practical considerations often place extreme limitations on the study objectives, especially in terms of the number of locations sampled or the total number of samples collected. A critical review of an excessively cost-limited study may show that the indoor data collected may be interesting but of no real value in supporting the planned objectives.

PRECISION

Measurement studies with reported precisions of indoor particulate data are virtually nonexistent in the literature. Designing precision determination into a study plan using collocated measurements is a very important consideration to qualify later interpretations of the data. The range of expected precisions, however, can be estimated from such factors as the amount of mass collected, the precision of the filter weighing process, and the precision of the flow control system. Typically ambient particulate samplers (those designed for outdoors) have coefficients of variation of ± 3-10% while the smaller and lower flow microenvironmental indoor samplers could be expected to be in the ± 3-15% range with the appropriate quality control. Personal exposure samplers have very low flowrates and marginal flow controllers and are usually more variable with an expected precision range of ± 5-25%. The precisions for the microenvironmental and PEM samplers can be even larger for a sampler designed to be used indoors but also used outdoors without regard to factors such as the wind speed dependency of the inlet or the effect of temperature on the flow system.

ACCURACY

Sampling accuracy is difficult to quantify for particulate samplers. With no available standard reference system, accuracy can only be inferred from components of the measurement process, such as flow control or filter weighing. Accuracy includes the consideration of the representativeness of the measurement as compared to how the data are to be interpreted. If, for example, fixed location microenvironment measurements in the living room are used to assess the 24-hour exposure of residents to particles or SVOC's, some knowledge of the expected spatial and temporal variability must be available. The presence of particles greater than about 2 μm* associated with significant air movements, such as from a fan or vent, can have a substantial impact on the effectiveness of the sampler inlet, thus providing inaccurate measurements. A field comparison of the indoor sampler with a well characterized ambient sampler such as the dichotomous sampler may provide the most useful indicator of overall accuracy.

*All particle dimensions refer to aerodynamic diameter.

Particulate and SVOC samplers drawing an air stream through a substrate must collect an amount of material consistent with the analytical capabilities. Table 1 lists the amount of mass collected (at 100% efficiency) by several commonly used particulate samplers at 30 $\mu g/m^3$ for various sampling times and flow rates. Collection of less than 1000 μg of particles on the substrate for gravimetric analysis necessitates the use of a microbalance. Total collections of less than 100 μm/substrate invariably result in poor precision. Unfortunately, most of the higher flow rate samplers are very obtrusive with excessive noise levels unless the pump modules can be placed outdoors. Collection of particles for surface analysis techniques, such as microscopy or x-ray fluorescence, requires limited mass, needing only enough material to form a uniform monolayer. Without gravimetric analyses, however, these data are difficult to either interpret or translate into concentrations.

OBTRUSIVENESS

The obtrusiveness of samplers used indoors is an extremely important factor. An occupant will not allow a noisy sampler to remain either in a work or home environment. A sampler that is too large or invites probing from children or pets is also unwanted. Two of the microenvironment samplers in Table 1 have been packaged expressly with at least the noise aspect carefully controlled. The Harvard Aerosol Impactor and the 8 CFM prototype sampler built for EPA by Battelle are virtually noiseless in an indoor environment. The 8 CFM sampler, however, accomplishes this using a large and heavy soundproof box which would limit its utility to only larger microenvironments. The sampling head for the dichotomous sampler can be made reasonably unobtrusive if the pump module can be located outdoors and the tripod legs removed.

UTILITY OUTDOORS

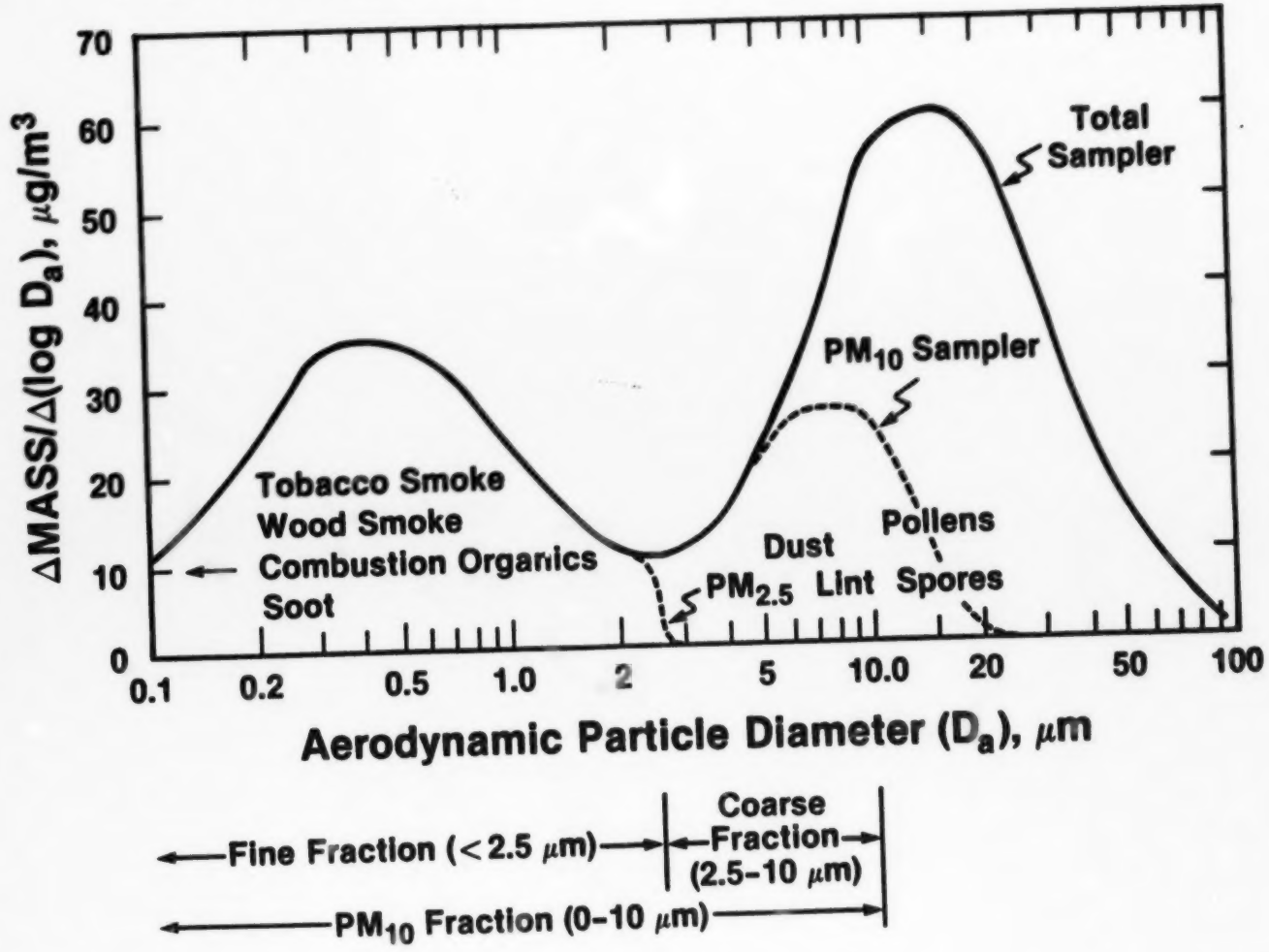
As noted earlier, some of the available samplers were developed strictly for the indoor environment and are not suitable for outdoor conditions. Many indoor studies require a knowledge of the concurrent outdoor concentration levels in order to assess infiltration effects. Utilization of samplers

with identical performance in both locations is important to the computation of accurate indoor/outdoor ratios. As discussed in more detail in the next section, the performance of aerosol sampling inlets under different wind speeds can have a profound effect on the concentration results for larger particles. The representativeness of the outdoor sampling location is also critical. Sampling too near a residence with a wood stove, for example, may give erroneously higher fine particle concentrations caused by a plume downwash. Sampling more than a few hundred meters from the residence can conversely cause erroneously lower results because of coarse particle concentration gradients.

PARTICLE SIZE DISTRIBUTION

Particles suspended in the air exist as a bimodal distribution of aerodynamic sizes with substantial differences in composition and character. The mass distribution shown in Figure 1 is an example of an outdoor atmosphere sampled by a cascade impactor capable of efficiently sampling particles as large as 100 μm. The dashed lines indicate the proportion of this "total" distribution collected by PM_{10} and $PM_{2.5}$ samplers. The "fine" fraction typically contains the combustion products including adsorbed organics, while the "coarse" fraction is composed primarily of reentrained and agglomerated particles. Similar distribution data for indoor environments are virtually nonexistent, but the composition of the coarse fraction could be expected to differ substantially from those outdoors. Recent work suggests that a significant number of occupant complaints about the indoor environment may stem from biologically active coarse particles including aeroallergens and from occupant sensitivity to reentrained dusts, fibers, and dander from carpeting. These particles are found primarily in the coarse mode and are best identified through microscopy using a sampler that segregates by particle size. Most monitoring studies to date have collected only the fine fraction, thereby providing little information in the literature on the indoor coarse fraction composition. Note that tobacco smoke is generated (and found) mostly in the fine fraction, although some constituents may be adsorbed and agglomerated onto larger particles.

Figure 1. Indoor Sampling Fractions Related to a Typical Ambient Particulate Mass Distribution



The performance of the inlet system is critical to accurate sampling of the particulate distribution. Because of their aerodynamic properties particles are separated as a function of their particle size. Figure 2 compares the collection effectiveness data for a $PM_{2.5}$ dichotomous separator, an ambient PM_{10} inlet that meets the requirements of the proposed EPA Federal Reference Method, and the inlet of the prototype indoor microenvironmental sampler developed by NBS for EPA. The dichotomous separator and the Sierra/-Andersen PM_{10} inlet are virtually insensitive to wind speeds from 2 to 24 km/hr. The NBS inlet, however, is quite sensitive and could produce substantially different sample collections for indoor and outdoor locations.

FILTER SUBSTRATE

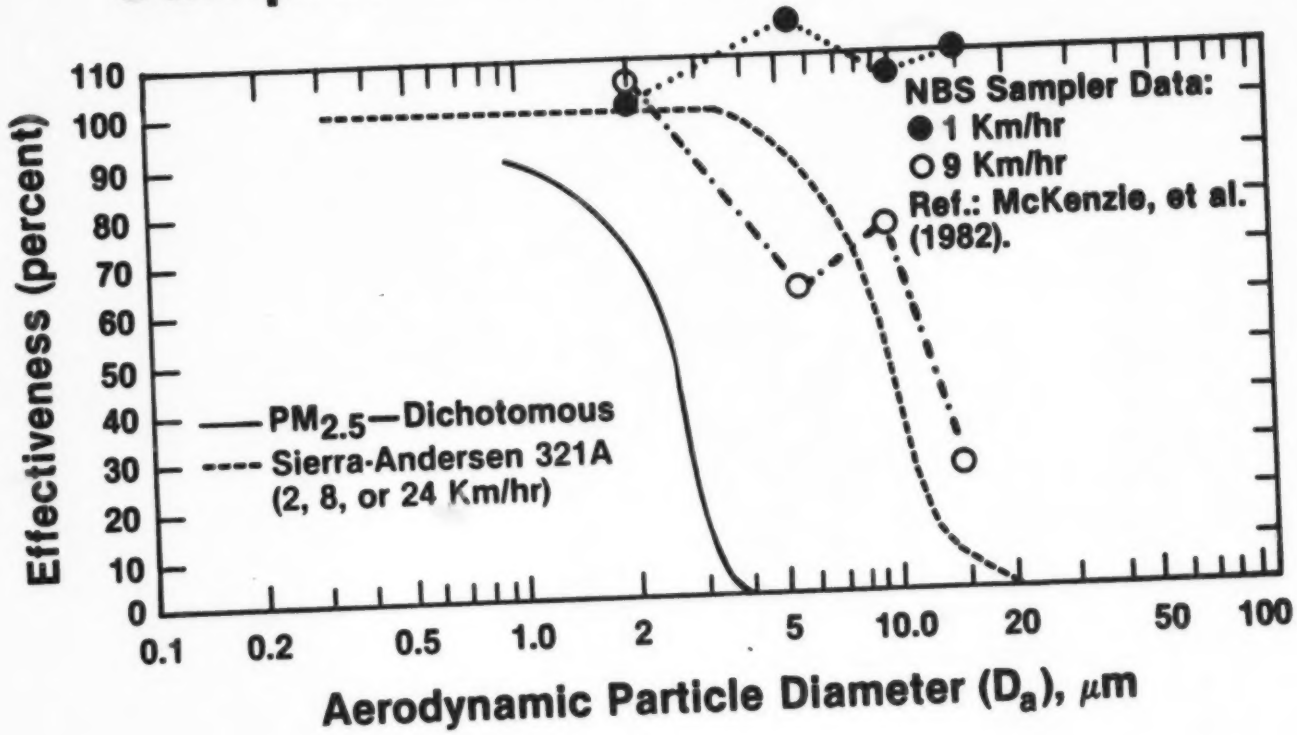
The collection surface must be tailored to the type of analyses anticipated. Although most filters are very efficient for trapping particles (see Table 2), filters made of glass fiber can add artifact mass if any acid gases are present. The virtually unreactive quartz filters are excellent but must be handled carefully to prevent damage. Cassettes are available for several filter types and sizes to minimize the effect of handling and prevent particle loss. Membrane filters, such as Teflon or Nuclepore,* are utilized if measurements requiring the particles to be retained at the filter surface are to be made. Analyses for organics from the extracts of these filters may, however, be impossible. Teflon filters with a 2 μm porosity are an excellent general purpose choice for indoor sampling and are widely used in dichotomous samplers and the Harvard Aerosol Impactor. An important consideration for choice of substrates is the pressure drop increase as particle loading increases. Fine, sticky particles, such as those from tobacco smoke can completely plug membrane filters such as Teflon in less than 24 hours if the concentrations are excessive.

SEMIVOLATILE ORGANIC COMPOUNDS

Because of their presence in the gas and particle phase, the degree of volatility of the SVOC's must be considered. The ideal collection system uses a quartz (or other low background) filter substrate followed by a vapor

*Mention of a trade name does not constitute endorsement by EPA.

Figure 2. Selected Particulate Sampler Effectiveness Curves



trap. The two media can be analyzed separately or together. The distribution between phases is temperature dependent, and indoor versus outdoor relationships will be different especially during winter conditions. The concentration necessary to permit detection analytically must be factored into the flow rate and sampling time. Table 3 lists sampling requirements for the 8 CFM Battelle sampler. Typical indoor sampler flow rates of 2-4 ℓ/min often will not collect enough material in a 24-hour period unless the concentrations are significantly high.

The volatile phase sampling substrates most often used are polyurethane foam (PUF) and XAD-2. The XAD-2 collects compounds with a wider range of vapor pressures but is substantially more expensive and difficult to preclean. The design of the vapor phase substrate holder must be tested for optimum face velocity and residence time to quantify collection and retention characteristics. A PUF sampler design used extensively in screening studies at EPA is commercially available from Andersen Samplers.* The more research oriented Integrated Air Cancer Program at EPA has used XAD-2 cartridges to sample inside and outside of residences for wood stove emissions. A 10 ℓ/min PUF cartridge is currently being tested for use in line with a quartz prefilter. The design of the cartridge for SVOC sampling must also permit airtight closure for shipping and handling. The volatile phase substrates can be contaminated very easily by exposure to sources other than the intended environment. It is currently unclear as to the cold storage temperature required to control SVOC stability on the substrate, but household freezer temperature (~ 0°F) can be considered adequate for shipping and storage.

A most important factor to consider for SVOC's is the cost per sample for GC/MS analysis. After the list of compounds to be detected is selected, the lab should provide a cost estimate and the time required for analysis (including substrate precleaning). The cost per sample almost always severely limits the number of samples that can be precleaned and analyzed. Note that substrate precleaning may cost as much as subsequent analysis. Even if the sampling objectives must be modified because of a required reduction in the number of samples collected, the designer must still be sure to quantify the precision in the field with collocated sampling and the level (if any) of field blank contamination. Precision data are mandatory to validate the collected sample data.

TABLE 1. QUANTITY OF PARTICLES COLLECTED FOR SELECTED SAMPLERS AS A FUNCTION OF FLOWRATE AND SAMPLING PERIOD

SAMPLER	TYPE[a]	FLOWRATE ℓ/m	SAMPLING PERIOD, hrs					
			1	3	6	12	24	168
HARVARD/EPRI	PEM	1.8	3[c]	10	19	39	78	544
HARVARD AEROSOL IMPACTOR	μE	4	7	43	86	86	173	1,210
NBS PROTOTYPE	μE	6	11	32	65	130	259	1,814
EPA PROTOTYPE[b]	μE	10	18	54	108	216	432	3,024
DICHOTOMOUS[b] SAMPLER	A/μE	16.7	30	90	180	360	720	5,050
1-CFM ANDERSEN IMPACTOR[b]	A/μE	28.3	51	153	306	612	1,223	8,564
4-CFM ANDERSEN	A/μE	113	204	612	1,224	2,448	4,896	34,262
8-CFM BATTELLE (prototype)	μE	226	408	1,224	2,448	4,896	9,792	68,524
PM_{10} HI VOL	A	1,133	2,039	6,118	12,236	24,473	48,946	342,619

[a]Legend: PEM - Personal (portable) exposure monitor
μE - Microenvironment sampler
A - Ambient

[b]Sample divided between 2 or more substrates.

[c]Mass in μg for an air concentration of 30 $\mu g/m^3$.

TABLE 2. FRACTIONAL PENETRATION OF PARTICLES THROUGH SELECTED CLEAN FILTERS WITH A PRESSURE DROP OF 30 mm Hg

Type	Face Velocity, cm/sec	Penetration for D_p in μm			
		0.035	0.10	0.30	1.0
Gelman Type A glass fiber	32.7	<0.0001	<0.0001	<0.0001	<0.0001
Pallflex 2500, quartz fiber	65.5	<0.006	0.008	0.0006	0.0004
Millipore cellulose MF RA, 1.2 μm	16.5	<0.0001	<0.0001	na	na
Nuclepore N800, 8 μm	72	1.00	0.98	0.88	0.45
Teflon, 2 μm	64.1	0.0011	0.00008	<0.00007	<0.00009

Ref: Liu, B.Y.H., Pui, D.Y.H., and K. L. Rubow. "Characteristics of Air Sampling Filter Media," Chap. 70 in Aerosols in the Mining and Industrial Work Environment, pp 989-1038, Ann Arbor Science, Ann Arbor, MI, 1983.

TABLE 3. ESTIMATED SAMPLING REQUIREMENTS FOR SELECTED SVOC's

Compound	Estimated concentration in ambient air, ng/m^3(a)	Estimated quantification level, mg/sample(b)	Required sampling time 8 cfm, minutes
PAH's (GC/MS)			
Phenanthrene	5	50	45
Pyrene	2	50	110
Chrysene	1.5	20	60
Benzo(a)pyrene	0.5	20	180
Benzo(g,h,i)Perylene	1.0	20	90
Coronene	0.5	20	180
1-Nitropyrene	0.1	5	220
Dioxin (2,3,7,8-TCDD)(c)	0.001	0.2	890
PCB's (GC/ECD)	10	200	90
Pesticides (GC/ECD)			
Chlordane	100	200	10
Dichlorvos	50	20	2
Malathion	100	40	2
Ronnel	10	40	18

(a) Estimates in nanograms/m^3 based on the lower limit of levels reported in the literature.

(b) Quantification level in milligrams/sample is 3 to 4 times the instrumental detection limit.

(c) Indoor air data not available. Unpublished ambient air data used for this estimate.

REF: Howes, J.E., T. Merriman, C.A. Ortiz, and A.R. McFarland, "Final Report on Development of a Sampler for Particulate-Associated and Low Volatility Organic Pollutants in Residential Air," EPA Contract No. 68-02-3487, WA-39, Battelle Columbus Laboratories, Columbus, OH 43201

SELECTED REFERENCES FOR INDOOR PARTICULATE AND SVOC SAMPLING

Agarwal, J. K. and B.Y.H. Liu. "A Criterion for Accurate Aerosol Sampling in Calm Air," AIHAJ, Vol. 41, No. 3, pp 191-197, 1980.

Colome, S. D., Spengler, J. D., and S. McCarthy. "Comparisons of Elements and Inorganic Compounds Inside and Outside of Residences, Env. Int., Vol. 8, pp 197-212, 1982.

Environmental Protection Agency, "Quality Assurance Handbook for Air Pollution Measurement Systems: Volume 1. Principles," publication EPA-600/9-76-005, Research Triangle Park, NC 27711, Dec. 1984.

Fletcher, R. A. "A Review of Personal/Portable Airborne Particulate Monitors," JAPCA, Vol. 34, No. 10, pp 1014-1016, 1984.

Howes, J. E., Merriman, T., Ortiz, C. A., and A. R. McFarland. "Final Report on Development of a Sampler for Particulate-Associated and Low-Volatility Organic Pollutants in Residential Air," EPA Contract No. 68-02-3487, WA-39, Battelle Columbus Laboratories, Columbus, OH 43201, May 1985.

Lewis, R. G. "Problems Associated with Sampling for Semi-Volatile Organic Chemicals in Air," presented at EPA/APCA Symposium on Measurement of Toxic Air Pollutants, Raleigh, NC, April 1986.

Lippmann, M. "Size-Selective Health Hazard Sampling," Chapter H in Air Sampling Instruments for Evaluation of Atmospheric Contaminants, American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 1983.

Liu, B.Y.H., Pui, D.Y.H., and K. L. Rubow. "Characteristics of Air Sampling Filter Media," Chapter 70 in Aerosols in the Mining and Industrial Work Environment, pp 989-1038, Ann Arbor Science, Ann Arbor, MI, 1983.

Marple, V. A. and J. E. McCormack, "Personal Sampling Impactor with Respirable Aerosol Penetration Characteristics," AIHAJ, Vol. 44, No. 12, pp 916-922, 1983.

Martonen, T., Clark, M., Nelson, D., Willard, D., and E. Rossignal. "Evaluation of a Mini-Cascade Impactor for Sampling Exposure Chamber Atmospheres," Fund. & App. Tox., Vol. 2, pp 149-152.

McKenzie, R. L., Bright, D. S., Fletcher, R. A., and J. A. Hodgeson. "Development of a Personal Exposure Monitor for Two Sizes of Inhalable Particulates," Env. Int., Vol 8, pp 229-233, 1982.

Nagda, N. L., Fortmann, R. C., Koontz, M. D., and H. E. Rector. "Comparison of Instrumentation for Microenvironmental Monitoring of Respirable Particulates," paper 85-30A.1, presented at 78th Annual Meeting of the Air Pollution Control Assoc., Detroit, MI, June 1985.

Ott, W. R. "Total Human Exposure," ES&T, Vol. 19, No. 10, pp 880-886, 1985.

Rubow, K. L., Marple, V. A., Olin, J., and M. A. McCawley. "A Personal Cascade Impactor: Design Evaluation and Calibration," Particle Technology Laboratory, Pub. No. 469, Univ. of Minnesota, Minneapolis, MN, April 1985.

Sexton, K., Spengler, J. D., and R. D. Treitman, "Effects of Residential Wood Combustion on Indoor Air Quality: A Case Study in Waterbury, Vermont," Atmos. Env., Vol. 18, No. 7, pp 1371-1383, 1984.

Spengler, J. D., Treitman, R. D., Tosteson, T. D., Mage, D. T., and M. L. Soczek, "Personal Exposures to Respirable Particles and Implications for Air Pollution Epidemiology," ES&T, Vol. 19, No. 8, pp 700-707, 1985.

Turner, W. A., Spengler, J. D., Dockery, D. W., and S. D. Colome. "Design and Performance of a Reliable Personal Monitoring System for Respirable Particulates," JAPCA, Vol. 29, No. 7, pp 747-749, 1979.

Turner, W. A., Spengler, J. D., and V. A. Marple, "Indoor Aerosol Impactor," presented at EPA National Symposium on Recent Advances in Measurement of Air Pollutants, Raleigh, NC, May 1985.

Vo-Dinh, T. and D. W. Abbott, "A Ranking Index to Characterize Polynuclear Aromatic Pollutants in Environmental Samples," Env. Int., Vol. 10, pp 299-304, 1984.

U.S. Dept. of Energy, Indoor Air Quality Environmental Information Handbook: Combustion Sources, publication number DOE/EV/10450-1, Washington, DC 20585, January 1985.

Wallace, L. A. and W. R. Ott. "Personal Monitors: A State-of-the-Art Survey," JAPCA, Vol. 32, No. 6, pp 601-610, 1982.

Yocom, J. E. "Indoor-Outdoor Air Quality Relationships," JAPCA, Vol. 32, No. 5, pp 500-520, 1982.